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# New technique for measuring the microwave penetration depth in high-$T_c$ superconducting thin films

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**Abstract**

The ferromagnetic resonance (FMR) technique has been used to obtain the microwave (MW) penetration depth in high-temperature superconductor (HTSC) thin film. An FMR-signal-generating thin permalloy film was sandwiched in between of two $YBa_2Cu_3O_7$ films to probe the MW field penetrating through the films. Below the superconducting transition temperature $T_c$ the HTSC films started to screen the marker inside the sandwich. The low-temperature saturation value $\lambda_{ab} \simeq 1250$ Å at 25 K has been deduced for our *c*-axis films from the temperature dependence of the FMR signal intensity below $T_c$. 

*Keywords:* Ferromagnetic resonance; Microwave surface impedance; Penetration depth; YBaCuO films

## 1. Introduction

Since the discovery of the HTSC [1] numerous scientific studies have been undertaken to understand the nature of HTSC by using various experimental techniques. Such techniques as stripline resonator [2], surface impedance [3–6], microwave transmission [7] have recently been employed to obtain penetration depth values. Experimental results have been almost always controversial with conflicting results which are usually attributed to varying sample quality.

In this study, we have tried a new, simple and very sensitive technique to measure the penetration depth. High-quality $YBa_2Cu_3O_7$ (YBCO) thin films (750, 950 and 1900 Å thick) on MgO substrates have been studied through the FMR spectroscopy in order to obtain MW penetration depth as a function of temperature. The ferromagnetic marker, a permalloy (Py) thin layer (about 1000 Å thick) has been sealed between two YBCO films and placed in the ESR spectrometer cavity. Below $T_c$, the penetrating MW field would be damped exponentially through YBCO films lowering the MW power on the Py. Therefore, the FMR signal intensity is expected to be a direct measure of the average MW penetration depth $\lambda$ within YBCO. The FMR marker has advantages which are high signal-to-noise ratio and nearly temperature-independent intrinsic FMR signal far below the Curie temperature of Py.

## 2. Sample preparation

YBCO films are prepared by RF magnetron sputtering on polished MgO substrates in a UHV chamber. Judged by XRD (002)/(005) = 0.003 peak ratio the films have been identified as *c*-axis. $T_c$ of as-prepared films, measured by the resistive technique, was 80–85 K, and the critical current density ranged about 106 A/cm$^2$ at low temperatures. The films were spun with photoresist immediately after deposition and cut into $3 \times 3$ mm pieces to fit in the sample holder. After rinsing the photoresist, the FMR-signal-generating Py layer with an Au buffer

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